

13.0 CONCLUSIONS AND RECOMMENDATIONS

13.1 OVERALL CONCLUSIONS

Based on the investigation and evaluation conducted, the FTIHWG has concluded the following:

Service History

- There is a close relationship between the incidence of explosions in wing tanks and the use of “wide-cut aviation fuel.”
- Wing tanks operating with less volatile Jet A type fuel have demonstrated an acceptable safety record.
- In comparison, heated CWTs are more vulnerable to explosion in the presence of ignition sources.
- The three most recent events (1990 Manila, 1996 New York, and 2001 Bangkok) form the basis for forecasting future events.
- Inerting fuel tanks may enhance occupant survival in accidents in which a fuel tank explosion is the primary cause.

Safety Assessment

- Because the fuel tank explosion rate has been statistically shown to be fairly consistent, the actual occurrence of incidents will increase in the future as a result of forecasted fleet growth.
- Ignition source reduction activities associated with SFAR no. 88 are expected to provide a reduction in the fuel tank explosion rate.
- Inerting systems will offer little benefit to three categories of airplanes studied: regional turboprops, regional turbofans, and business jets. These categories of airplanes do not have heated CWTs, and the flammability exposure of the wing tanks is already low.
- The flammability exposure levels achieved by inerting systems can result in an improvement in the accident rate.

Ground-Based Inerting (GBI and OBGI)

- Installing the airplane portion of a GBI system does not require any new technology to be developed. However, retrofit GBI systems will be extremely difficult and will require an evaluation of each airplane category model to determine if a retrofit installation is practical.
- The availability of airport supply systems to supply NEA at each terminal gate and remote parking area is a serious problem that needs to be resolved before GBI can be implemented.
- Development of a new NEA-to-airplane interface panel and associated components is necessary and requires agreement on configuration and control for a worldwide standard before a GBI system operation is practical.
- OBGIS was the heaviest system evaluated. System size is determined by the relatively short turnaround time between existing commercial flights at the gate and by the large ullage volumes (small fuel load) required for short missions.
- Because an OBGIS runs only on the ground, interference with other airplane systems would be minimized and the certification process should be simpler.

Airport Facilities

- Before promulgating an airplane GBI requirement, it will be necessary to resolve the current lack of global regulatory authority and industry control over the introduction and construction of new airport inerting supply systems, either fixed or mobile.
- Developing, constructing, and integrating into the current airport infrastructure fixed inerting equipment for large and medium-sized airports will be a major problem.

- Test data from elementary testing, using nitrogen and carbon dioxide, indicated that ullage washing and fuel scrubbing with either gas has little effect on the conventional properties of jet fuel. However, a measurable change in vapor pressure occurred as a result of fuel scrubbing, and the carbon dioxide-scrubbed fuel had an increase in acidity.
- Significant quantities of VOC were released during both processes, regardless of the inert gas used. This increase in VOC emissions should be investigated and resolved to avoid any serious potential health, environmental, and safety issues.
- Because a fuel cooling process does not address the scenario of operating with an empty CWT, this system of reducing flammability exposure was not pursued.
- The lack of NEA availability at smaller airports currently used as diversion airports for larger hubs would affect airline operations. In addition, if GBI is not implemented worldwide, the impact may be significant on non-U.S. diversion airports or those used for technical stops.

Onboard Inert Gas Generating System

- An OBIGGS would reduce the flammability exposure to almost zero, except when the airplane is not powered, operating under the MEL, or is in a nonnormal operational mode.
- When the OBIGGS is installed, noise reduction measures may have to be taken as a result of system compressor and fan noise.
- The electrical power requirements to run an OBIGGS are large and constitute a majority of the total electrical power available on an airplane category.
- The weight of an installed OBIGGS is significant; for example, for a large transport category airplane, the OBIGGS weighs between 1,120 and 1,600 lb.
- Retrofit of OBIGGS will require an evaluation of each airplane category model to determine if a retrofit installation is practical for that airplane model.
- Current technology components of an OBIGGS have demonstrated low reliability.
- Technological advancements that will decrease the complexity, size, weight, and electrical power requirements of an OBIGGS are needed.
- NEA membrane air separation systems that have improved efficiency and performance, and lower nonrecurring costs would be a necessary part of a practical membrane-type OBIGGS.
- For cryogenic systems, basic research into high-efficiency, vacuum-jacketed heat exchangers and lighter, more efficient cryogenic refrigerators is required to achieve a practical cryogenic-type OBIGGS.

Hybrid Systems (OBGI and OBIGGS)

- The issues and resolutions for hybrid systems are similar to their respective full-sized systems stated above.
- The OBGIS provides a reduction in flammability exposure comparable to that of the GBI system.
- The hybrid OBGIS is almost as large as the full-sized OBGIS.
- A hybrid OBIGGS that would provide the flammability exposure of a GBI system is the smallest onboard system of all onboard designs.

Airplane Operations and Maintenance

- The Tasking Statement defined an inerting system with little or no redundancy as a basis for this evaluation. Therefore, no inerting design concept evaluated was considered flight critical and airplanes could be dispatched with an inoperative inerting system (MEL). This assumption is fundamental to the technical and cost conclusions reached by this report.
- If the inerting system is not included in the MEL, then the complexity and cost of the system design concepts and airplane operational impact evaluated in this study would be significantly increased.

- If inerting systems are required to be installed in existing in-service airplanes, the resultant maintenance burden on the airline industry will be substantial and there may not be sufficient modification facilities, depending on the allowed modification incorporation time period and skilled personnel available.
- The current reliability of inerting system technology is unacceptable from a maintenance and operational viewpoint and requires an order of magnitude improvement to make them operationally viable.

Estimating and Forecasting

- The cost-benefit methods used by the FTIHWG to determine a practical inerting system were the same as the economic analysis practices used by the FAA.
- Based on the above economic analysis, none of the inerting design system concepts studied were found to be reasonably balanced by their incurred costs.
- Of the design concepts studied, the one with the lowest cost-benefit ratio was the GBI and the hybrid OBIGGS concept applicable to heated CWTs only.
- There is little difference in system costs between in-service and current production of a particular airplane model except for higher (20% to 30%) installation costs for retrofit of service airplanes and associated airplanes because of downtime during installation. Also, with today's technology, there is little difference in system cost between current production and new type design airplanes.

Regulatory Impact

- Because this evaluation has not found a practical fuel tank inerting system, a new 14 CFR regulatory text should not be proposed.
- The environmental and regulatory impact of any future practical fuel tank inerting system needs to be addressed by the appropriate regulatory organizations when such a system is developed and proposed.
- Any requirement to incorporate a fuel tank inerting system would significantly affect existing CFR Title 14 parts, for example, Airworthiness Standards: Transport Category Airplanes (Part 25), Flight Operations (Parts 91 and 121), and possibly Airport Facilities.

13.2 RECOMMENDATIONS

The ARAC FTIHWG specifically recommends the following actions to be expeditiously carried out by the FAA, NASA, and the industry:

Inerting Systems

- Continue to evaluate and, where appropriate, investigate means to achieve a practical onboard fuel tank inerting system design concept for future new type design airplanes.
- Pursue technological advancements that would result in onboard fuel tank inerting designs having decreased complexity, size, weight, and electrical power requirements, and increased efficiency, reliability, and maintainability.
- Perform NEA membrane research to improve the efficiency and performance of membranes resulting in lower nonrecurring costs of NEA membrane air separation systems, for example, basic polymer research to increase the operational temperature of membranes to a level above 302°F.
- Conduct basic research into high-efficiency, vacuum-jacketed heat exchangers, and lighter, more efficient cryogenic refrigerators for use in inerting systems.
- If a practical means of achieving a cost-beneficial fuel tank inerting system is found, establish a corresponding minimum flammability level and reevaluate and propose regulatory texts and guidance materials accordingly.

Fuel Tank Flammability

- Evaluate means to reduce fuel tank flammability based on existing (e.g., directed ventilation, insulation) or new technology that might be introduced sooner into the in-service fleet and current airplane production.
- Initiate a project to improve and substantiate current flammability and ignitability analyses to better predict when airplane fuel tank ullage mixtures are flammable. This research is needed to support informed design decisions and rulemaking.
- Initiate a project to thoroughly document and substantiate the flammability model used in this study.